§66. Effect of Halo Neutrals from Bulk Ions on Fast-ion Charge Exchange Spectroscopy in LHD

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Estimation of the velocity and spatial distributions of the fast ions is important subject to understand the physics of the fast-ion-driven MHD activities and to estimate the confinement property of the fast ions. Fast ion charge exchange spectroscopy (FICXS) has been demonstrated to measure the fast ion distributions in LHD [1)]. The effect of the halo neutrals on FICXS has been pointed out [2)]: The halo neutral H_{halo} is produced by the CX reaction between the neutral beam atom H_{NB} and the bulk ion H_b^+ (i.e. $H_b^+ + H_{NB} \rightarrow H_{halo} + H_{NB}^+$). The emission from H_{halo} by the collisional excitation with fast ions (i.e. $H_f^+ + H_{halo} \rightarrow H_f(n>1) + H_{halo}^+$) affects FICXS since this component would be localized along the neutral beam path and cannot be subtracted using the background sightline. In this study, we investigate the spatial profile of the halo neutrals aiming at estimating the effect of halo neutrals on FICXS.

The spatial distribution of the halo neutrals was calculated using a Monte-Carlo neutral particle transport simulation code (DEGAS). In this calculation, we introduced the following assumptions to simulate the halo neutrals: (1) The birthpoints of the halo neutrals are the same as those of the beam ions. (2) The initial velocity and its direction of the halo neutral are determined from the bulk ion temperature with Maxwell distribution using random numbers. The recycling coefficient at the wall is unity.

The test calculation was carried out using the plasma mesh model and beam birthpoint for Heliotron J. Figure 1 shows the spatial distribution of the birthpoints of beam ions for the co-going beam line (BL2). In the case of the BL2 beam energy of 27 keV, the cross section of the CX reaction which produces the halo neutral is about twice as that for the ionization for beam ions. The electron density is assumed to be 2×10^{19} m^{-3} at the plasma core and the electron and ion temperature is 0.4keV and 0.25keV, respectively. The density and temperature profiles are to be parabolic them. A full-torus mesh model is used for the calculation: 512, 28 and 15 sections in the toroidal, poloidal and radial directions, respectively. The material of the vacuum wall is assumed to be iron which is the main component of the stainless steel used for the Heliotron J vacuum vessel.

Figure 2 shows the spatial profile of the atomic neutral density at the horizontal plane acrossing the magnetic axis. The halo neutral density is higher in the beam path region. The decay length of the halo neutral density in the toroidal direction is around 10 cm. Note that the radial profile of the halo neutral density differs from the distribution of its birthpoint. The neutral density at the plasma edge is 10 times higher than that at the magnetic axis: Since the halo neutrals with the velocity corresponding to the ion temperature have a mean free path of around several tens cm, it can escape from the plasma region and contacts with the wall surface. In this calculation, the species of the reflected neutrals (H or H_2) is determined by the reflection coefficient of halo neutral, which depends on the incident energy and angle onto the wall. When the hydrogen molecule is selected, the velocity of the recycled hydrogen molecule is determined at the wall temperature (T=300K). The recycling source of the hydrogen molecule with the wall temperature may cause the neutral density profile in the radial direction. Therefore, the species, energy and recycling coefficient of the reflected neutrals are important to evaluate the precise distribution of the halo neutrals in Heliotron J.

The spectrum of the fast ion charge exchange will be calculated using the fast ion energy distribution by FIT. This calculation scheme will be applied into the LHD plasmas to estimate the halo neutral components in FICXS.

1) M. Osakabe, et al., IAEA-FEC2010, EXW/P7-22.
2) T. Ito, et al, PFR **5**, S2099 (2010).

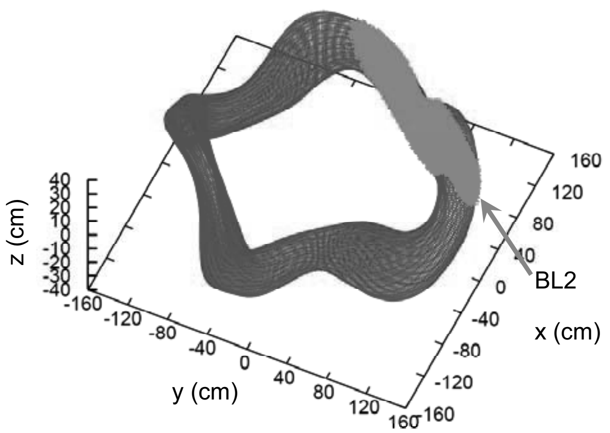

Fig. 1. Plasma mesh model and birthpoints of the halo neutrals used in the simulation.

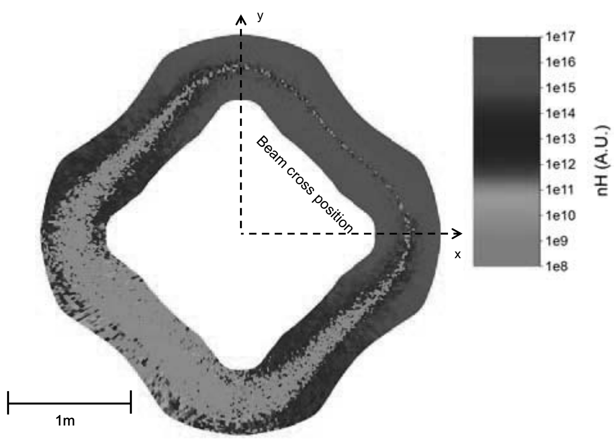

Fig. 2. 2-dimensional distribution of the atomic hydrogen density originated in the halo neutrals.